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AUTHOR Norman, John T.
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ABSTRACT

The purpose of this investigation was to determine the effect of a middle school inservice course emphasizing science process skills on the development of integrated process skills and on logical thinking. Twenty-two middle-school science teachers from the Detroit Public Schools participated in this project. A "Resourcebook of Science Process Skills" was developed for use with middle school students (grades 5-9) and was used with teachers in this inservice course. For each of the 11 process skills a generic science activity was presented as well as one applicable to the subject areas of life science, earth science, and physical science. Application questions were posed in each process chapter. Teachers were taught two strategies for teaching these processes to their students, namely the learning cycle and a modeling strategy. The following conclusions about middle school science teachers were made: (1) they can make significant gains in the mastery of science process skills from an inservice course emphasizing science process skills; (2) they can make significant gains in their logical thinking from an inservice course emphasizing science process skills; and (3) they may have great difficulty in learning instructional strategies for teaching their process skills to their students. References and tables are provided. (MVL)

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THE EFFECT OF A MIDDLE SCHOOL TEACHER INSERVICE COURSE EMPHASIZING SCIENCE PROCESS SKILLS ON THE DEVELOPMENT OF INTEGRATED PROCESS SKILLS AND LOGICAL THINKING

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John T. Norman
Science Education
College of Education
Wayne State University
Detroit, Michigan 48202

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THE EFFECT OF A MIDDLE SCHOOL TEACHER INSERVICE COURSE EMPHASIZING SCIENCE PROCESS SKILLS ON THE DEVELOPMENT OF INTEGRATED PROCESS SKILLS AND LOGICAL THINKING

ABSTRACT

The relationship between integrated process skill achievement and logical thinking has been demonstrated. However, there have been few studies dealing with successful inservice approaches for the development of teacher abilities in integrated process skills and in logical thinking. It has been hypothesized that teachers receiving mastery training in science processes will be more effective classroom teachers with regard to the development of science processes and logical thinking of their students.

The purpose of this investigation was to determine the effect of a middle school inservice course emphasizing science process skills on the development of integrated process skills and on logical thinking. Twenty-two (N = 22) middle school science teachers from the Detroit Public Schools participated in this project. A Resourcebook of Science Process Skills was developed by the author for use with middle school students (grades 5-9) and was used with teachers in this inservice course. Chapters in this book included the following topics: (1) Observing, (2) Classifying, (3) Measuring, (4) Constructing Bar Graphs and Pie Graphs, (5) Predicting, (6) Making Scatterplots and Line Graphs, (7) Operationally Defining Variables, (8) Identifying Variables, (9) Describing Relationship Between Variables, (10) Formulating Hypotheses, and (11) Conducting Experiments and Drawing Conclusions. For each process skill a generic science activity was presented as well as one applicable to the subject areas of life science, earth science, and physical science. Application questions were posed in each process chapter.

One inservice session of about two-and-one-half hours was spent for each of the processes. Teachers were taught these processes using an activity approach. Furthermore, the teachers were taught two strategies for teaching these processes to their students, namely the Learning Cycle and a Modeling Strategy. Teachers were required to develop a lesson plan for each of the integrated processes (#6-11)

The Group Assessment of Logical Thinking (GALT) and the Middle Grades Integrated Process Skill Test (MIPT) were administered to these inservice teachers both before and after the inservice course. Correlated t-tests were done to determine gains. Significant gains were found for the teachers in both logical thinking and in their knowledge of integrated process skills. However, the teachers seemed to have great difficulty in learning the two teaching strategies as evidenced by their lesson plans.

The following conclusions were made: (1) Middle School science teachers can make significant gains in the mastery of science process skills from an inservice course emphasizing science process skills; (2) Middle School science teachers can make significant gains in their logical thinking from an inservice course emphasizing science process skills; and (3) Middle School science teachers had great difficulty in learning instructional strategies for teaching their process skills to their students.

Introduction

The development of a student's inquiry and problem solving skills has been agreed upon as as essential goal of science education (Gagne, 1965; NSTA 1971; & NSTA, 1983) These skills have been identified by the commission in Science Education of the American Association for the Advancement of Science as consisting of eleven science processes of which certain ones are considered basic and prerequisite to others which are called integrated processes.(Gagne, 1965)

However, there is evidence that the majority of our middle school students are unable to use integrated science processes in planning and conducting an investigation.(Tobin & Capie, 1980; Rubin & Norman, 1989) Furthermore, these same middle school students are also deficient in their development of logical thinking abilities.(Garnett & Tobin; Rubin & Norman, 1989) Furthermore, development of these logical thinking abilities and process skills seems to be related to general achievement in school (Lawson, 1982a; Padilla, Okey, & Dillashaw, 1983).

It is an assumption of this study that these student deficits in science process skills and in logical thinking are partly the result of inadequately prepared teachers. Teachers who have not learned process skills themselves will have difficulty in using them in problem-solving situations with students. (Lawrenz & Cohen, 1985) Teachers who are at a concrete or transitional level of logical thinking will have difficulty in promoting higher thinking skills of their students. Teachers who lack effective instructional strategies will have difficulty in teaching process skills or logical thinking to their students. Furthermore, it is assumed that teachers that have deficits in their process skills, logical thinking abilities, and/or instructional strategies can overcome many of these deficits in an inservice course of sufficient duration.

Background

Definitions

The emphasis on science process skills and logical thinking in instruction would have been described by Piaget as an emphasis on operative knowledge as opposed to figurative knowledge. According to Piaget, operative knowledge transforms states through mental action that is either physical or covert, whereas figurative knowledge involves knowing that something is the case. Operative knowledge may be described as "knowing how" to do certain things, such as measuring the length of an object or making a graph. Whereas, figurative knowledge may be described as "knowing that" something is the case, such as that Mars is a planet or that bacteria lack a clearly defined nucleus. (Lawson, 1982b)

More recently, J.B. Anderson (1985) referred to such an emphasis on process skills or logical thinking that we know how to perform as "procedural knowledge" as opposed to "declarative knowledge" which is the information or facts that we know. Procedural knowledge, according to Anderson, has a problem solving orientation.

Piaget has described the major changes in logical thinking that occur during childhood. However, there is some debate today as to what causes these changes. One point of view is that children "think better" and the other is that they "know better." The think better point of view maintains that children's basic cognitive procedural knowledge (processes) are better; whereas, the know better viewpoint maintains that children have learned more declarative knowledge (facts) as they grow older, enabling them to perform the Piagetian tasks more effectively (Anderson, 1985). Anderson maintains that this is not an either-or situation, rather, the child's improvement is due to both factors.

Piaget has argued that the development of operative (or procedural) knowledge is necessary for the learning of specific figurative (or declarative) knowledge. (Lawson, 1982b) Linn (1982), however, has advocated that more attention should be given to non-developmental "practical factors" that may influence whether a student can apply a theoretically available strategy. One of these practical factors she advocated was the effect of educational intervention to change reasoning.

Teacher Education and Process Skill Development

There are several studies of successful attempts to intervene to improve the process skills of preservice teachers, but few studies have been reported with inservice teachers.

Examples of factors that have been successful with preservice teachers in improving their process skills include: 1) specific methods courses emphasizing basic and integrated process skills (Janus, 1975); Bluhm, 1975; Jones, 1983; Scharmann, Harty, & Holland, 1986; Jones & Norman, 1989); 2) cooperative learning mode of presentation (Baird, 1986); and 3) preservice (and inservice) teacher training approaches that incorporate a combination or "practice-analysis-feedback." (Yeany & Padilla, 1986) Field experiences without such a systematic combination have not been found to increase inquiry oriented concerns of pre-service teachers. (Strawitz & Malone, 1987; Lawrenz & Cohen, 1985)

Studies with inservice teachers have been sparse. Aiello-Nicosia and Associates (1984) reported that the teacher's ability to control variables (procedural knowledge) is more important than their understanding of science processes (declarative knowledge) for student achievement.

Teacher Education and Logical Thinking Development

There are numerous studies related to the logical thinking of preservice

teachers, but few studies dealing with inservice teachers.

Garnett and Tobin (1984) assessed the logical thinking of preservice teachers and found that large numbers of preservice teachers could not use formal reasoning.

Lawson and Snitgen (1982) also found much evidence in the literature for failure of many college students to use formal reasoning strategies. Furthermore, they found that a one semester course emphasizing components of formal reasoning could significantly improve a preservice elementary teacher's ability to reason formally.

Bowyer and associates (1987) evaluated staff development materials designed to help high school teachers to use formal reasoning strategies. They found 1) 8-16 hours was the minimum inservice time needed to learn these strategies; 2) the best inservice programs were sponsored by local school districts; 3) providing classroom practice between staff development sessions did not seem to affect teachers' reported intentions to use the workshop ideas, and 4) the key importance of a strong, active administrator to offer peer teacher support.

Relationship Between Integrated Process Skills and Logical Thinking

Schneider and Renner (1980) found that students who experienced the learning cycle strategy made larger gains in logical thinking as well as content achievement and retention of gains.

Jones (1983) found that preservice elementary teachers exposed to a methods course emphasizing basic and integrated process skills made significant gains in logical thinking when compared to a control group. Furthermore, she found a fairly high correlation between a student's score on a test of integrated process skills and their score on a logical thinking test.

Padilla, Okey, and Dillashaw (1983) examined the relationships between

integrated process skills and formal thinking abilities of middle/high school students. They found that science process skill ability is strongly associated with logical thinking.

Purpose

The purpose of this investigation was to determine the effect of a middle school inservice course emphasizing science process skills on the development of integrated process skills and on logical thinking. The specific questions addressed in the study were:

1. Will middle school science teachers who have taken a course emphasizing science process skills significantly improve their achievement of integrated process skills?
2. Will middle school science teachers who have taken a course emphasizing science process skills significantly improve their logical thinking?
3. Is there a significant relationship between middle school teachers' integrated process skills and their logical thinking?

Method

Subjects

The subjects in this study were a group of 22 middle school science teachers from a large urban school district who were enrolled in a science education course at Wayne State University. The school district paid their tuition fees and sponsored the inservice course. The average years of teaching experience of this group was 12 years. Only 6 of the 22 teachers had science majors and at least 6 of the 22 teachers had no majors or minors in science. Eig f the 22 teachers subscribe to a professional science education

or science journal. Only six of the 22 teachers belong to a local or national professional science teachers organization.

Procedures

The twenty-two middle school science teachers completed a course at Wayne State University that was structured around basic and integrated science process skills. Furthermore, several instructional strategies (The Learning Cycle and Systematic Modeling) were modeled and emphasized as means for helping to teach these process skills. There was a total of ten sessions of three hours each.

A Resourcebook of Science Process Skills (Norman, 1988) was developed for use with middle school students and was used with teachers in this inservice course. Chapters in this book included the following topics: 1) Observing, 2) Classifying, 3) Measuring, 4) Constructing Bar Graphs and Pie Graphs, 5) Predicting, 6) Making Scatterplots and Line Graphs, 7) Operationally Defining Variables, 8) Identifying Variables, 9) Describing Relationships Between Variables, 10) Formulating Hypotheses, and 11) Conducting Experiments and Drawing Conclusions. For each process skill a generic science activity was presented as well as one applicable to the subject areas of life science, earth science, and physical science. Application questions were posed in each process chapter. In addition, the book Learning Science Process Skills, by Funk and associates (1985) was used as a teacher reference book.

Teachers were required to develop a lesson plan for each of the integrated science processes. Also, they were required to incorporate one of the two instructional strategies in their plans.

Opportunities were provided in the class for extensive practice of each newly learned process skill. Teachers were asked to identify lessons in their

middle school science textbooks that illustrated each of these process skills. Furthermore, each teacher was asked to present one of their lesson plans to a small group of their peers for analysis and feedback.

The Middle Grades Integrated Process Skill Test (MIPT) developed by Cronin and Padilla (1986) was given as a pretest and posttest to measure the teachers' ability to use integrated science process skills. This test was developed from test items from Dillashaw and Okey's (1980) Test of Integrated Process Skills. Content validity was established by giving the test to a panel of experts in science education. The panel was asked to match test items to outcomes. Also, they were asked to verify the scoring key. Experts agreed with developers 95% of the time. The experts agreed on the scoring of the items 97% of the time. The reliability was calculated by Cronin and Padilla (1986) with a Kuder-Richardsen value of 0.89.

The Group Assessment of Logical Thinking (GALT) developed by Roadrangka, Yeany, and Padilla (1983) was given as a pretest and posttest to measure the teachers' level of concrete and formal reasoning. The validity of this test was determined by correlating subject scores with traditional Piagetian interview tasks and obtaining an $r = 0.71$. (Yeany, Yap, & Padilla, 1986) The reliability of the total test was measured by Cronback's alpha as 0.75. (Yeany, Yap, & Padilla, 1986) The subjects used in these validation and reliability studies were 551 students ranging in grade level from 6 to college.

Correlated t tests were done to measure the gains from pretest to posttest on both the MIPT and the GALT. In addition, correlations were made between the teacher's scores on the MIPT and GALT.

Results

The means and standard deviation for both the Middle Grades Integrated

Process Test (MIPT) and the Group Assessment of Logical Thinking (GALT) for both the pretest and the posttest can be found in Table I. The average scores on the pretest of logical thinking were at the low end of a transitional logical thinking level (5.32); whereas, the average pretest scores on the integrated process skills test was at a more average level (20.41).

The results of correlated t-test comparisons between pretest and posttest scores on both the MIPT and GALT are presented in Table II. The teachers' scores on the MIPT showed a significant gain from pretest to posttest ($p < .01$). Also, the teachers' scores in the GALT also showed a significant gain from pretest to posttest ($p < .001$).

Histograms were made of the teachers' scores on the GALT pretest and on the GALT posttest to demonstrate the teachers' growth in logical thinking (Tables III and IV). From comparing these two histograms, one can observe that in the pretest there were 10 out of 22 teachers who tested at the concrete level of logical thinking (0-4 correct items); whereas, on the posttest only 4 out of 22 teachers tested at the concrete level. Similar comparisons can be made to show the growth of logical thinking in the other intervals of the histogram.

In order to determine the relationship between integrated process skills and logical thinking, correlations were made between the MIPT and GALT scores (Table V). These correlations were fairly high and were statistically significant ($p < .01$). For example, the correlation between the GALT pretest and the MIPT pretest was found to be 0.75 ($p < .001$).

An unexpected finding was the great difficulty many of the teachers had in completing the five written lesson plans illustrating how to teach integrated science processes using a particular learning strategy (Table VI). Only 14 of the 22 teachers completed the 5 lesson plans, and only 7 of these 14

demonstrated mastery of both integrated process skills and the assigned instructional strategy on all five of the assigned lesson plans. Mastery was indicated by a grade of "B" or better on their lesson plan. Teachers seemed to have much more trouble with the application of the instructional strategy to their lesson plan than with the incorporation of the integrated process skills.

Conclusions and Discussion

The following conclusions were made as a result of the data and observations from this study: 1) Middle school science teachers can make significant gains in the mastery of science process skills from an inservice course emphasizing science process skills; 2) Middle school science teachers can make significant gains in their logical thinking from an inservice course emphasizing science process skills; and 3) Middle school science teachers like those who participated in this study will have great difficulty in learning instructional strategies for teaching their process skills to students.

The results of this study support those of Jones (1983); & Lawson and Snitgen (1982) who found that a college course emphasizing process skills and/or logical thinking components could promote higher levels of logical thinking. These results also support Linn's contention that educational intervention can change reasoning strategies (Linn, 1982). This research also supports Piagetian contentions that adults should be capable of formal thinking.

This study also supports those of many other researchers who have shown that courses that emphasize process skills can result in significant growth of integrated process skill knowledge. (Janus, 1975; Bluhm, 1975; Jones, 1983; Scharmann, Harty, & Holland, 1986; Jones & Norman, 1989). The implications of these findings are that teachers lacking in process skills can be taught these skills, and hopefully they will become better teachers as a result.

The results of this study also support the finding of a strong relationship between knowledge of integrated process skills and logical thinking, as previously shown by Schneider and Renner (1980); Jones (1983), and Padilla, Okey, and Dillashaw (1983). Since both the test of logical thinking and the integrated process test are measures of procedural knowledge, and since many of the Piagetian operations are probably required for these integrated science processes, it should be no surprise that these two measures are highly related. These results also support the model of the hierarchical relationships among modes of reasoning and science process skills proposed by Yeany, Yap, and Padilla (1986).

There is also strong support in this study for the success of an inservice training approach that involves a combination of "practice-analysis-feedback" (Yeany & Padilla, 1986) as was done in this institute. In this study, the teachers were given much practice on integrated process skills through activities in class, as well as through assigned work outside of class, such as the written lesson plans. Analysis was done in class through modeled lessons and through "talk aloud" activities. Students were asked to analyze lessons from their peers and to give feedback to each other. The instructors also gave extensive feedback in class and in written assignments.

Furthermore, this study supports the finding that the best inservice programs are supported by local school districts, (Bowyer & Associates, 1987) as was done in this study.

The finding that inservice teachers had much trouble in developing lesson plans applying a learning cycle or systematic modeling strategy, was surprising. Perhaps this can be explained by the fact that the majority of these teachers were non-formal thinkers at the beginning of this study, and this may have caused them to have difficulty in applying an abstract strategy to a

lesson. Also, since many were deficient in their knowledge of integrated process skills, maybe they could only learn so much at one time. Perhaps it would have been best to learn the process skills first and later learn teaching strategies.

Questions for further study might be:

1. Are science teachers who have higher logical thinking scores more effective teachers?
2. Should science process instruction be structured as a series of isolated but sequenced units, or should science process instruction be integrated into problem solving in a holistic manner?
3. Does generic science process knowledge transfer from one subject area to another?
4. What is the relative contribution of declarative knowledge, and procedural knowledge to the changes in logical thinking of inservice teachers observed in this study?
5. How does the spacing of practice of science process skills affect learning?
6. Should declarative knowledge precede procedural knowledge in the learning of a process skill?

TABLE I

DESCRIPTIVE STATISTICS FOR PRE AND POST MEASURES OF INTEGRATED PROCESS SKILLS AND LOGICAL THINKING

MEASURE	N	MEAN	SD	MEDIAN	MINIMUM	MAXIMUM
Pre-test Integrated Process Test[a]	22	20.41	5.11	20.50	11.00	28.00
Posttest Integrated Process Test[a]	22	23.64	3.90	24.50	17.00	28.00
Pretest Logical Thinking Test[b]	22	5.32	3.31	5.50	1.00	12.00
Posttest Logical Thinking Test[b]	22	7.68	2.87	8.00	1.00	12.00

[a]Total test items = 28

[b]Total test items = 12

Scale: 0-4: Concrete Operational Level
5-7: Transitional Level
8-12: Formal Operational Level

TABLE II

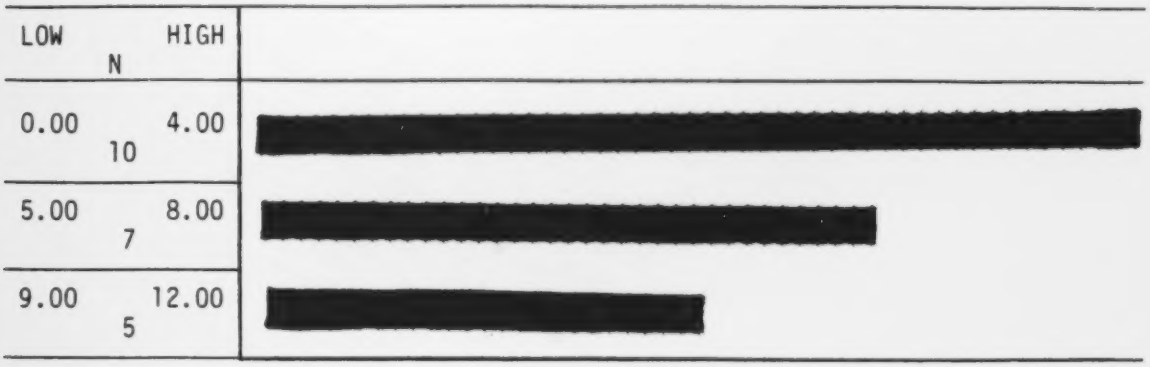
CORRELATED T-TEST COMPARISON BETWEEN PRETEST AND POSTTEST SCORES OF INTEGRATED PROCESS SKILLS AND LOGICAL THINKING

TEST	N	MEAN DIFFERENCE	S.E.	DIF.	t
Integrated Process Skills	22	3.23	.878	21	3.68*
Logical Thinking	22	2.36	.472	21	5.00**

* $p < .01$
** $p < .001$

TABLE III

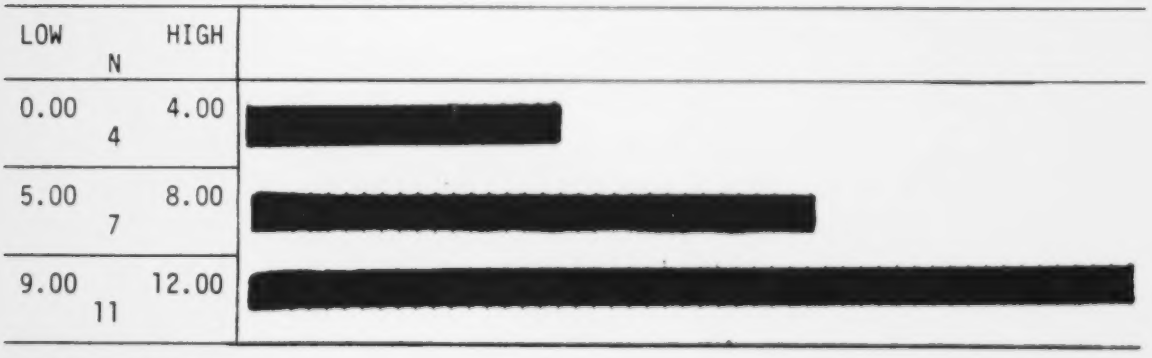
HISTOGRAM OF SCORES ON PRETEST OF LOGICAL THINKING



CASES INCLUDED: 22 MISSING CASES: 0

TABLE IV

HISTOGRAM OF SCORES ON POSTTEST OF LOGICAL THINKING



CASES INCLUDED: 22 MISSING CASES: 0

TABLE V

CORRELATIONS BETWEEN PRE AND POSTTEST MEASURES OF INTEGRATED PROCESS SKILLS AND LOGICAL THINKING

	Integrated Process Skills (Pretest)	Integrated Process Skills (Posttest)	Logical Thinking (Pretest)
Integrated Process Skills (Posttest)	.61*		
Logical Thinking (Pretest)	.75**	.60*	
Logical Thinking (Posttest)	.66*	.59*	.75**

*$p < .01$
**$p < .001$

TABLE VI

TEACHERS' MASTERY OF INTEGRATED SCIENCE PROCESS SKILLS AND AND TEACHING STRATEGY AS REFLECTED ON WRITTEN LESSON PLANS

Teacher Number	Number of Completed Lesson Plans[a]	Number of Lesson Plans Completed Indicating Mastery Of Integrated Process Skills And Strategy[b]
1	1	0[c]
2	5	5
3	5	4
4	4	3
5	5	5
6	4	1
7	2	2[c]
8	5	5
9	5	2
10	5	4
11	4	2
12	5	2
13	0	0[c]
14	5	5
15	1	1
16	5	5
17	5	3
18	5	4
19	5	5
20	2	0[c]
21	5	5
22	5	2

[a]Five Lesson Plans Required

[b]Mastery Based on a Grade of "B" or Better on Each Lesson Plan

[c]Missed Many Classes Due to Illness or to Personal Problems

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